ENVIRONMENTAL INFLUENCES ON ANGLING SUCCESS FOR LARGEMOUTH BASS

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ABSTRACT

Controlled angling was performed over a 35 day sampling period, during which 59 largemouth bass (*Micropterus salmoides*) were caught. Environmental conditions were monitored and analyzed with the null hypothesis that angling success is independent of environmental changes. Data revealed that success using a deep diving lure in 3 m of water peaked during morning (6 AM to 12 PM) and evening (6 PM to 9 PM) and was lowest at night (9 PM to 6 AM). The larger largemouth bass tended to be caught most frequently during low light levels (dawn and dusk) while the smaller ones were caught most often during high light (midday). Angling success was highest at the onset of fall overturn when the surface temperature cooled to 18-21 C from a summer high of 27 C. Success was inversely related to the amount of cloud cover. Angling efficiency was high during the full moons and low in transition periods between moon phases; all other moon phases showed the expected catch rates. Wind direction, wind magnitude, barometric pressure, and solunar periods revealed no significant relationship to angling. These results indicate that light is the most significant factor analyzed that affects the feeding behavior and activity of the largemouth bass.

INTRODUCTION

The largemouth bass (*Micropterus salmoides*) is one of the most popular sport fishes in the United States. For some time, fishermen and fishery managers have been interested in the feeding behavior of this common predator, especially as related to angling success (Hackney and Linkous 1978). Although there has been much research concerning largemouth bass activity and feeding habits, little is known about the relation of these habits to various environmental conditions (Howick and O'Brien 1983). Such information would be useful to anglers to determine when largemouth bass are most likely to be caught. Fishery managers could benefit as well, for they may be guided to the best time and place to sample as well as learning information that may be valuable for devising new management techniques.

One of the better known environmental effects upon largemouth bass is the correlation between angling success and time of day. Many anglers are well aware that large largemouth bass are frequently caught in the early morning and late evening. Small largemouth bass (less than 250 mm total length) are most active during the daylight (Elliott 1976, Lemons and Crawshaw 1985). Reynolds and Casterlin (1976) found that the activity of small largemouth bass peaks at dawn, dusk, and midday. Howick and O'Brien (1983) determined that the effect of light intensity on the perception of prey varies for different size largemouth bass. During daylight, bluegills (*Lepomis macrochirus*) of all sizes located largemouth bass of all sizes before they were seen. At low light intensities (simulating sunrise and sunset), largemouth bass could see the larger bluegills (greater than 40 mm total length) before they were seen. However, smaller bluegills were less frequently detected and consequently could see the largemouth bass first even at low light levels. The authors hypothesized that, because larger largemouth bass feed on larger bluegills, they gain an advantage by feeding at dawn and dusk. Those largemouth bass that feed on smaller prey must feed at higher light levels even though the prey has the advantage.

Another fairly common environmental influence upon largemouth bass behavior is that of water temperature. When surface temperatures are below 10 C, largemouth bass are very inactive and often go into a state of dormancy (Johnson and Charlton 1960, Lemons and Crawshaw 1985). When surface temperatures rise above 25 C, they often take refuge in the deep, cool regions of lakes (Block et al. 1984). Warden and Lorio (1975) found that largemouth bass activity peaked seasonally during spring heating (from 10 to 20 C) and fall cooling (from 27 to 10 C). They moved into shallow areas more frequently during these times than in the summer.

The relationships between other environmental factors and largemouth bass behavior have not been well documented. In a study by Warden and Lorio (1975), largemouth bass holding in 2 to 4.5 m of water were unaffected by varying wind direction, wind velocity, and barometric pressure. Although sky condition was found to be unrelated to activity, it did influence the location of largemouth bass - they were found to occupy shallow water more during cloudy days than sunny days.

Knight (1987) stated that combined solar and lunar (solunar) forces trigger daily activity of fish and wildlife, though no evidence was provided. Solunar activity consists of major feeding periods (during high and low tides) and minor feeding periods (midway between the majors). Larsen (1982) reviewed a study in which 300 largemouth bass greater than 4500 g were caught (by angling) over a study period of 40 months. Sixty-one percent of these were caught during solunar periods (determined after the fishing took place) which represent 27 percent of each day. It was also found that most of these fish were caught within three days of a full or new moon. Analysis of world and state record catches revealed that about 90 percent of these large fish were caught within three days of a full or new moon and the rest were caught on a day of a half moon. Although significance levels and actual figures were not given, this review provides direction for the analysis of solunar and lunar influences upon angling success.

The objectives of this study are: 1) to determine if angling success for largemouth bass is influenced by time of day, sky condition, water temperature, wind direction, wind magnitude, barometric pressure, solunar periods, and lunar periods; 2) to hypothesize the mechanisms which lead to the observed angling success during each environmental condition; 3) to consider angling success as a measure of feeding activity; and 4) to compare the growth rates of largemouth bass caught within each solunar and lunar period.

METHODS - Study site

Bear Lake, Michigan, was the site of my field studies. The lake is located in Manistee County at 86 degrees longitude, 44.5 degrees latitude, 8 km from the eastern shore of Lake Michigan. Bear Lake is a natural, eutrophic lake with a surface area of 706 ha and a mean depth of approximately 5 m. The lake is almost entirely spring fed and seasonally drains into Lake Michigan by way of Little Bear Creek and the Manistee River. Common fish species include largemouth bass, bluegill, smallmouth bass (*Micropterus dolomieui*), walleye (*Stizostedion vitreum*), northern pike (*Esox lucius*), yellow perch (*Perca flavescens*), rock bass (*Ambloplites rupestris*), and bowfin (*Amia calva*).

Sampling Procedure

I chose three sites to perform controlled angling. Sites 1 and 2 had a depth of about 3.5 m and contained pondweeds (*Potamogeton* sp.) which extended to the water surface. Site 3 was characterized by entirely submersed pondweeds and a depth of 2.8 m. Angling consisted of casting a Bomber Model-A crankbait (black and white) with 12 lb. test monofilament line. During each fishing trip I recorded starting time, break times, ending time, wind direction (north, south, east, west, or none), wind magnitude (light, moderate, strong, or none), sky condition (sunny, cloudy, partly cloudy, or dark), and surface temperature. Each time I caught a largemouth bass I recorded the time caught, total length, and weight. Then I removed scales for growth calculation, marked (fin-clip) for recapture determination, and released all fish. Controlled angling was performed for an average of 4.5 hours per day every day from July 25 to August 30, 1988.

After sampling was completed, I obtained barometric pressure from local weather records. I calculated solunar major and minor periods as explained in Knight (1987). Lunar periods were calculated as in Larsen (1982): 3 days on either side of full and new moons, 12 hours on either side of half moons. Growth rates were estimated by scale analysis using the following equation: $Ln=(Sn/S)(L-a)+a$, where Ln is the total length at age n, Sn is the radius of annulus n, S is the scale radius, L is the total length, and a is the correction factor (Bagenal 1978). No validation was used for the growth calculations.

Data Analysis

I wrote a computer program to perform a chi-squared goodness of fit test for each environmental condition (Appendices A and B). The null hypothesis was "angling success for largemouth bass is independent of environmental conditions." The tests involved the following formulas: $Ei=(Ti/T)n$ where Ei is the expected number of largemouth bass caught in sub-condition i, Ti is the amount of time fished in sub-condition i, T is the total amount of time fished, and n is the total number of largemouth bass caught; and

$$X2=\sum_{i=1}^{s}(Oi-Ei)^2/Ei$$

where X2 is the chi-squared value, Oi is the observed number of largemouth bass caught in sub-condition i, and s is the number of sub-conditions (eg. when wind direction is the condition to be tested, there are s=5 sub-conditions: north, south, east, west, and none). Resulting chi-squared values were compared to critical values with alpha of .05, .01, or .005 and s-1 degrees of freedom (DeVore 1987). When X2 is greater than the corresponding critical value, the null hypothesis is refuted with significance alpha.

RESULTS

I fished a total of 157 hours and 18 minutes which consisted of 41 hours, 40 minutes at site 1, 55 hours, 5 minutes at site 2, and 60 hours, 33 minutes at site 3. Fifty-nine largemouth bass were caught - 7 at site 1, 33 at site 2, and 19 at site 3. Data were analyzed individually by site. Since the relationships between angling success and environmental conditions were similar for all sites, all data were pooled to obtain one result for each environmental condition.

Time of day was divided into eight sub-conditions in order to analyze distinct periods of the day. These included midnight (24:00-2:59), pre-sunrise (3:00-5:59), sunrise (6:00-8:59), late morning (9:00-11:59), midday (12:00-14:59), early evening (15:00-17:59), sunset (18:00-20:59), and post-sunset (21:00-23:59). The number of largemouth bass caught was higher than chi-squared expected values in the morning (6 AM to 12 PM) and evening (6 to 9 PM) and lower than the expected value at night (9 PM to 6 AM) (Figure 1). Angling success in relation to time of day was significant at the .005 level.

Angling success among various size largemouth bass revealed that as total length increased, a greater percentage was caught during low light periods (one hour before to two hours after sunrise and two hours before to one hour after sunset) although numbers caught were too small to allow statistical analysis

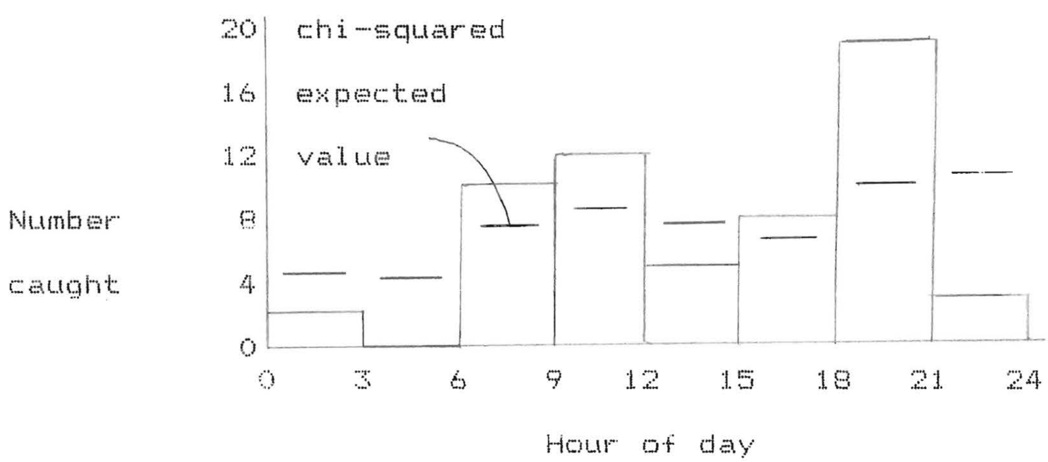

Figure 1: Number of largemouth bass caught during three-hour periods of day and expected values.

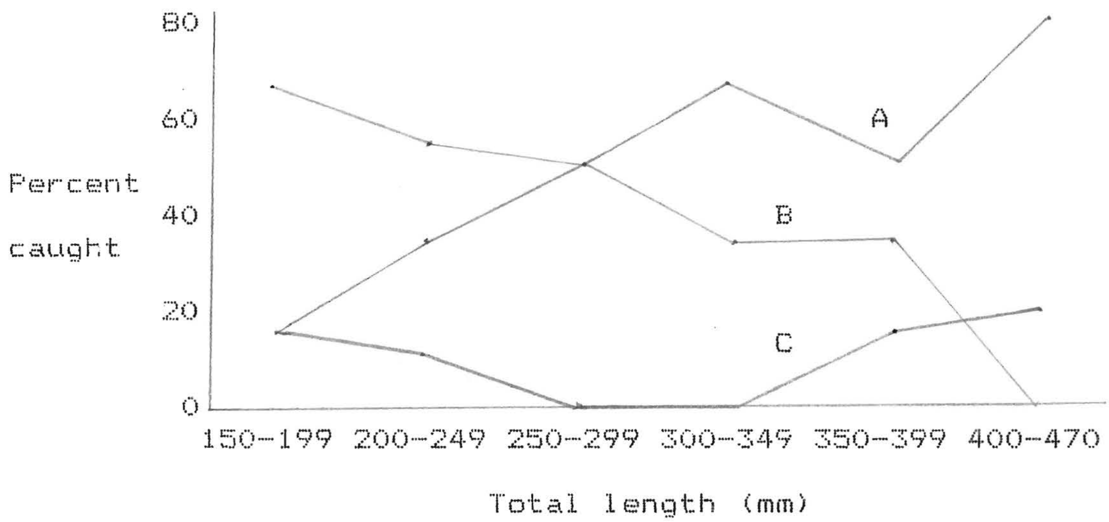

Figure 2: Percentage of largemouth bass of each size range caught during A) low-light levels, B) high-light levels, and C) night. The number of largemouth bass of each size range was 6 for 150-199, 9 for 200-249, 24 for 250-299, 9 for 300-349, 6 for 350-399, and 5 for 400-470.

(Figure 2). The percentage of largemouth bass of each size range that was caught during high light periods declined as total length increased. Due to the low number of largemouth bass caught at night, no relationship was observed with nocturnal angling success and size of largemouth bass. The number of largemouth bass of most size ranges was low; consequently the percentages can be highly influenced by one stray catch.

Surface water temperature was analyzed with three sub-conditions: 18 to 21 C, over 21 to 24 C, and over 24 to 27 C. The observed catch was much higher than the chi-squared expected values for the 18 to 21 C range while it was less than expected for the warmer temperatures (Figure 3). Water temperature influences were significant at the .005 level.

Angling success was affected by sky condition with a significance of .01 (Figure 4). Very few largemouth bass were caught during the dark periods (defined as those times before sunrise or after sunset). More largemouth bass were caught than the chi-squared expected value in sunny weather, while the number caught in cloudy and partly cloudy skies was nearly equal to the expected value.

The number of largemouth bass was higher than the expected value during the full moon, lower than expected during transitional periods (the periods between phases), and within the expected range for all other phases (Figure 5). The lunar influences upon angling success were significant at the .01 level.

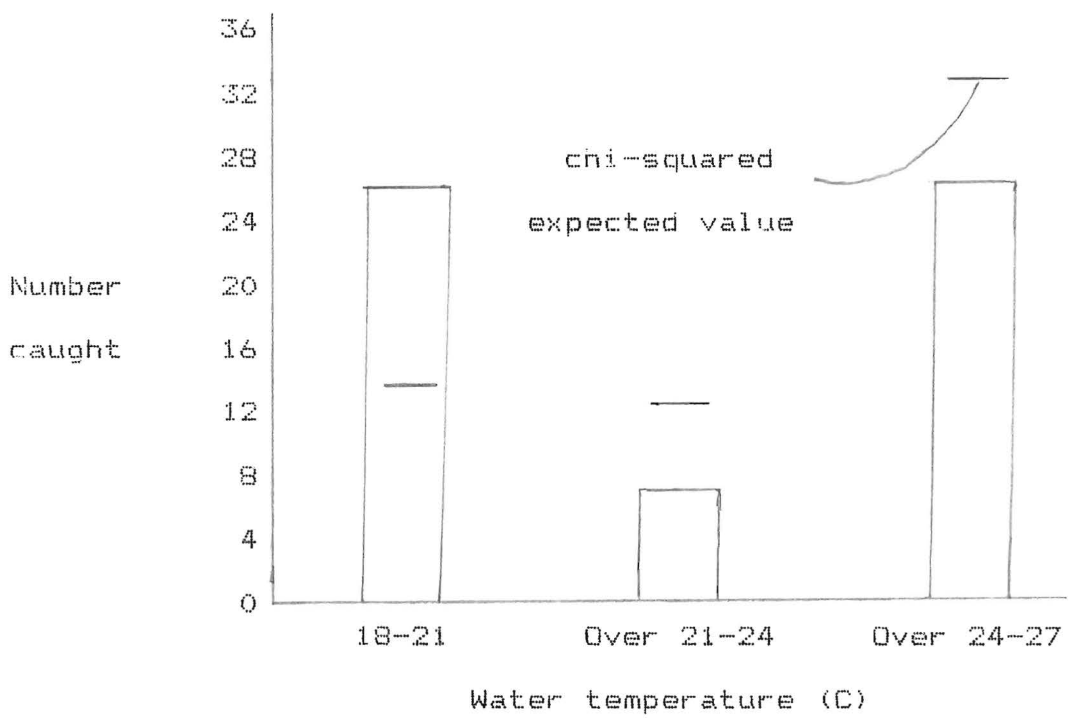

Figure 3: Number of largemouth bass caught during each surface temperature range and expected values.

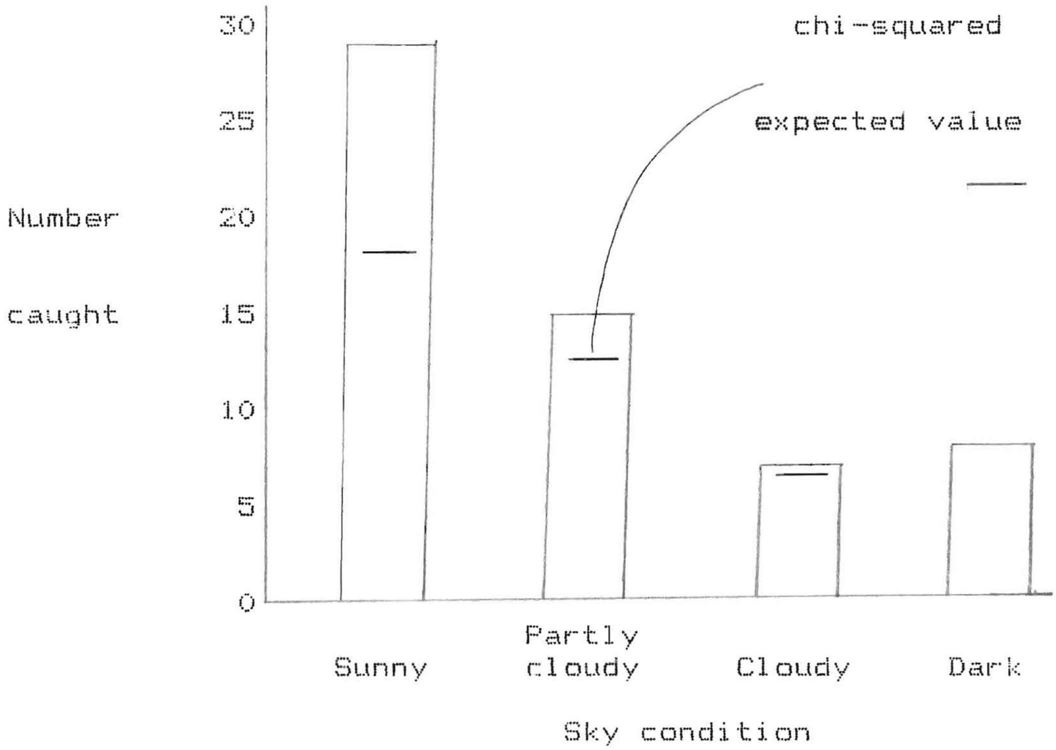

Figure 4: Number of largemouth bass caught during each sky condition and expected values.

The observed number of largemouth bass caught was nearly equal to the expected values for wind direction, wind magnitude, barometric pressure, and solunar periods (Figures 6, 7, 8, 9). None of these showed any significant deviation from the expected catch. However, fishing tended to be best when barometric pressure was rising, wind direction was west, wind magnitude was moderate, or when fishing outside of the solunar periods. Fishing tended to be least successful during steady pressure, south winds, strong winds, or during solunar periods. These trends must be held in question since they were not significant at the .05 level.

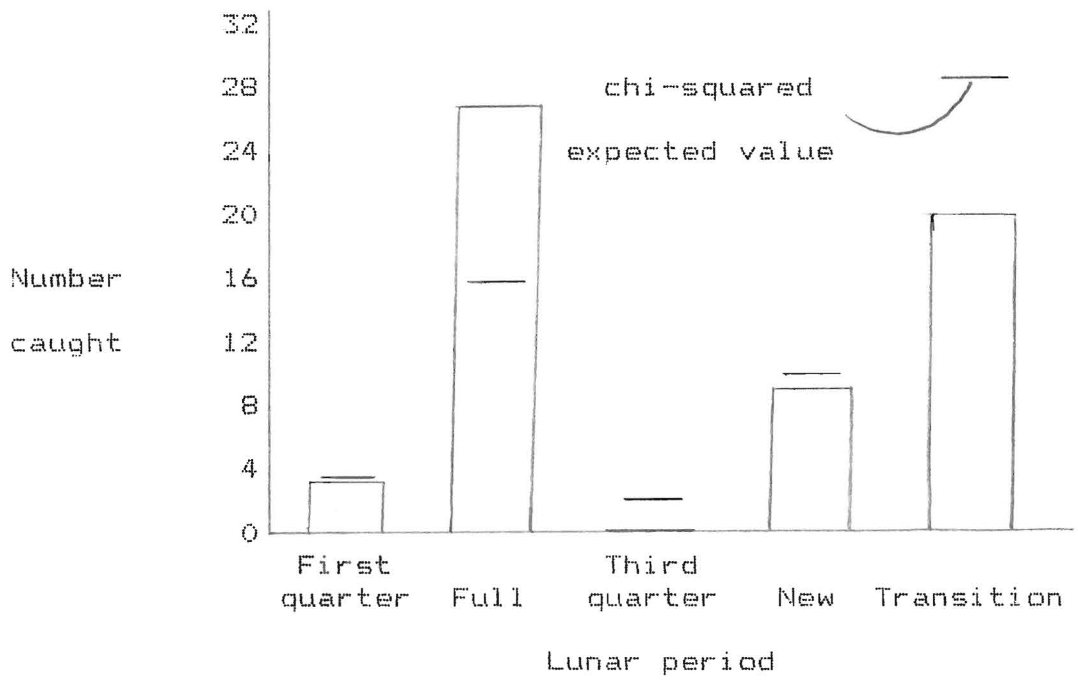

Figure 5: Number of largemouth bass caught during each lunar period and expected values.

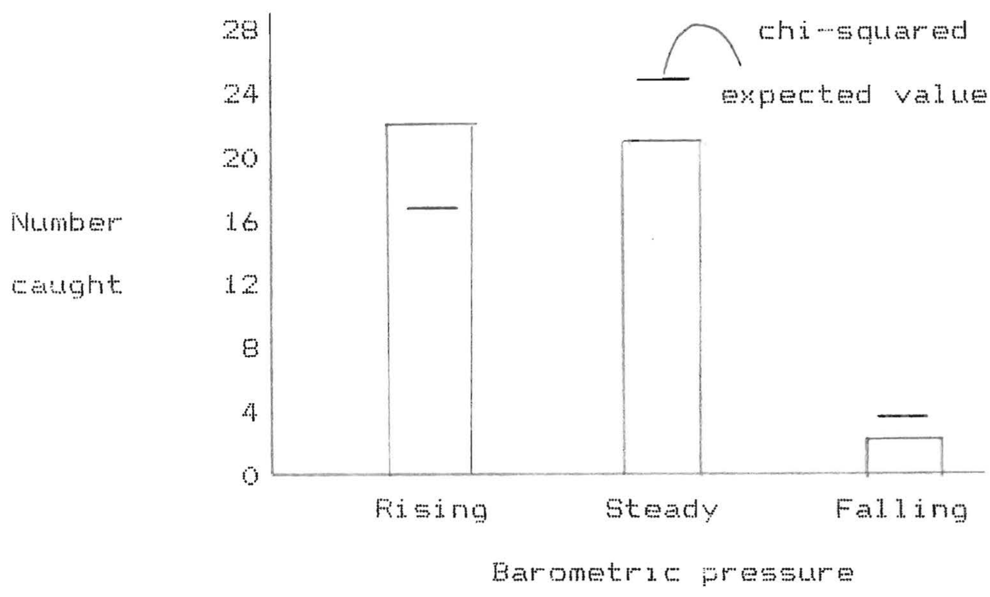

Figure 6: Number of largemouth bass caught during barometric pressure conditions and expected values.

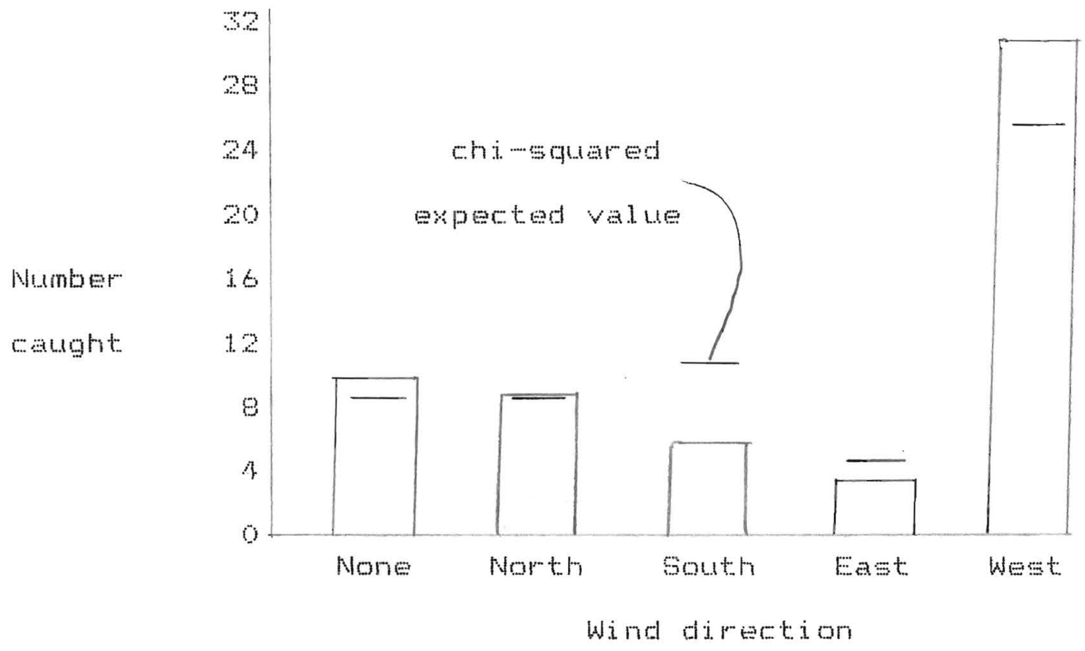

Figure 7: Number of largemouth bass caught during each wind direction and expected values.

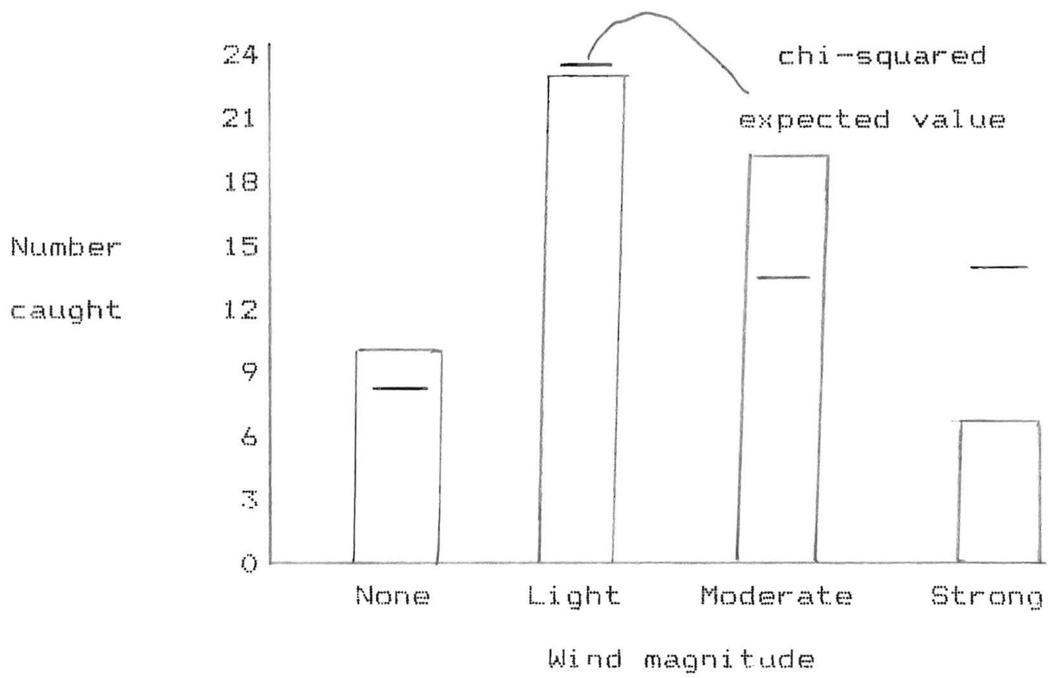

Figure 8: Number of largemouth bass caught during each wind magnitude and expected values.

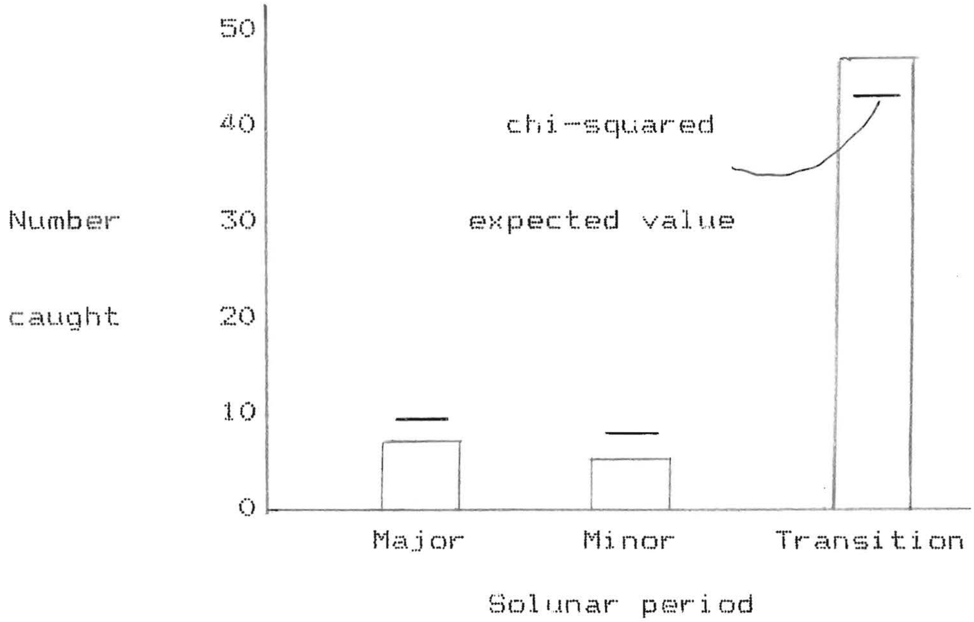

Figure 9: Number of largemouth bass caught during each solunar period and expected values.

Growth rates and length at age were fairly constant among largemouth bass caught in each solunar and lunar sub-condition (Table 1). My data indicate that growth and size of largemouth bass is independent of solunar and lunar forces. In fact, solunar forces appear to be nonexistent in relation to the catch rates altogether. While angling success was highest during the full moon and lowest in lunar transitional periods, these apparent influences were independent of the growth and size of the largemouth bass caught.

	Sub condition		1	II	III	IV	V	VI	VII
	Major:	ln	77	194	281	334	374	385	395
		(sd)	(27)	(17)	(-)	(-)	(-)	(-)	(-)
A)	Minor:	ln	89	213	292	332	382	-	-
		(sd)	(21)	(18)	(3)	(4)	(-)	(-)	(-)
	Transition:	ln	87	204	279	344	373	408	412
		(sd)	(27)	(25)	(27)	(24)	(30)	(33)	(-)
	1st quarter:	ln	60	188	-	-	-	-	-
		(sd)	(2)	(6)	(-)	(-)	(-)	(-)	(-)
	Full:	ln	89	210	289	336	371	402	412
		(sd)	(26)	(22)	(9)	(15)	(15)	(-)	(-)
B)	New:	ln	70	193	323	391	441	455	-
		(sd)	(19)	(18)	(-)	(-)	(-)	(-)	(-)
	Transition:	ln	81	193	269	344	363	386	395
		(sd)	(24)	(19)	(25)	(25)	(13)	(7)	(-)
C)	Bear Lake	ln	82	200	281	345	374	403	404
	Michigan	ln	81	165	244	315	343	358	378

Table 1: Average length (ln, in mm) and standard deviation (sd, in mm) of largemouth bass at each age - determined from back calculations of growth (using correction factor (a) of 24.07). A) solunar periods, B) lunar periods, and C) Bear Lake compared to the Michigan average from Carlander (1977).

DISCUSSION

Angling was more successful in the morning and evening than during midday and night, with presunset being the period with the highest capture frequency and efficiency and night being the one with the lowest catch rates. Diel activity varied for different size largemouth bass, revealing that larger ones were most often caught at sunrise and sunset while smaller ones were more commonly caught at midday. This supports the hypothesis of Howick and O'Brien (1983) which states that the larger largemouth bass gain an advantage by feeding during low light levels while smaller largemouth bass are forced to feed at midday. At night, very few fish were caught. This could have been a result of the following: 1) they were unable to catch the lure, 2) they did not feed at night, or 3) they moved into shallower, inshore regions of the lake and thus were not available for capture. Of these explanations, 1) seems most likely because the largemouth bass must sense the lure to strike it and be captured. The largemouth bass can sense the lure most by sight, though they may be able to detect it to some extent by vibration. At night, largemouth bass simply did not see the lure. Explanations 2) and 3) may be somewhat true, but I have no direct evidence to support these possible causes.

Angling success was highest during sunny weather and lowest in the dark. The sky conditions presumably follow a pattern with light intensity, where the intensity from highest to lowest is represented in order by sunny, partly cloudy, cloudy, and dark. The method of sampling is almost entirely a function of visibility (sight-feeding behavior of largemouth bass). With this reasoning, it follows that visual acuity should increase as the sky becomes clear (except after dark); the largemouth bass should be able to see the lure best at these times and consequently be most susceptible to capture. In addition, sky condition may be linked to migrational behavior of largemouth bass (Warden and Lorio 1975). They may be more likely to use the weedbeds for cover during high light intensities. If this is true, there would have been a positive relationship between light intensity and largemouth bass density (and therefore catch rates) on my sites. Because of these effects, sky condition in my study can only be used as a measure of angling success. Although this may reflect feeding activity on the sample sites, assuming that largemouth bass feeding activity is directly influenced by sky condition would be risky.

Fishing was best in the coolest surface-temperature range - 18 to 21 C. All of the fishing during this temperature range took place at the onset of fall overturn. Warden and Lorio (1975) found that largemouth bass were more active during this period of year than they were during the summer. This could be the reason for high catch rates in the cool water. However, because migration has been linked to water temperature changes (Warden and Lorio 1975, Block et al. 1984) and I fished the same sites over these changes, I cannot determine whether the fish were feeding more actively or if they simply were more abundant on my sites during the periods of lowest temperature. Therefore I cannot conclude that feeding activity increased in the cooler water. However, I can conclude that largemouth bass fed most actively at those specific sites when the surface temperature was lowest.

The highest angling success occurred during the full moon. The full moon of August took place at the same time that the water temperature was coolest. There is no way to tell whether the moon or the water temperature was responsible for the high angling success during this period in time since the variables are confounded. While all other conditions varied on a daily basis, water temperature changed only four times during the sampling period and moon phases vary only on a monthly basis. Because of this, these conditions probably could not have been adequately analyzed in my short sampling period of 35 days. Therefore, even if relationships do exist, this study cannot be used to reveal them.

Solunar periods were independent of angling success during this study and it appears that these influences are minimal or nonexistent upon angling success for 150-470 mm largemouth bass. Larsen (1982) indicated that solunar periods are correlated with the feeding behavior of large largemouth bass (greater than 4500 g). Since none of the fish caught at Bear Lake were even close to being large by this standard, I cannot say that my information contradicts that conclusion.

Wind direction and magnitude were not correlated with angling success to any significant degree. These influences may be significant in shallower waters (less than 2 m deep). Barometric pressure was also insignificant to angling success.

Although fish may be assumed to have been feeding when they are caught by angling (Hackney and Linkous 1978), caution should be taken before assumming that fishing success is directly related to feeding activity. This assumption could be biased by variable vulnerability to angling (Hackney and Linkous 1978, Burkett et al. 1986) and capture per strike values. In addition, seasonal and locational variations in activity patterns could change or even reverse largemouth bass behavior. Because of these unknown parameters, the application of these results may be limited to the specific sites and conditions encountered during the sampling period.

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APPENDIX A - COMPUTER PROGRAM

```
  10 CLS
  20 FOR X=1TO5
  30 INPUT "ENTER STARTING LUNAR DATE";LD(X)
  40 INPUT "ENTER ENDING LUNAR DATE";HD(X)
  50 INPUT "ENTER STARTING LUNAR TIME";LT(X)
  60 INPUT "ENTER ENDING LUNAR TIME";HT(X)
  70 NEXT X
  80 CLS
  90 INPUT "ENTER NUMBER OF FISH CAUGHT";F
 100 DATA 725, 2037, 2053, 1, 2, 2, W, L, 1
 110 REM * * * LINES 100 - 990 RESERVED FOR DATA * * *
 120 REM * * * DATA LINES MUST BE WRITTEN WITH CODES FOR EACH
     CONDITION IN ORDER AS FOLLOWS:  DATE, STARTING TIME, ENDING
     TIME, PRESSURE, SKY CONDITION, WATER TEMPERATURE, WIND
     DIRECTION, WIND MAGNITUDE, AND SOLUNAR PERIOD * * *
 130 REM * * * INTERPRETATION OF LINE 100:  I FISHED ON JULY 25
     FROM 2037 TO 2053, THE PRESSURE CODE WAS 1 (WHERE 1=STEADY,
     2=RISING, AND 3=FALLING), THE SKY-CONDITION CODE WAS 2
     (WHERE 1=SUNNY, 2=PARTLY CLOUDY, 3=CLOUDY, AND 4=DARK), THE
     WATER-TEMPERATURE CODE WAS 2 (WHERE 1=18 TO 21 C, 2=OVER 21
     TO 24 C, AND 3=OVER 24 TO 27 C), THE WIND-DIRECTION CODE WAS
     W (WHERE 0=NONE, N=NORTH, S=SOUTH, E=EAST, AND W=WEST), THE
     WIND-MAGNITUDE CODE WAS L (WHERE 0=NONE, L=LIGHT, S=STRONG,
     AND M=MODERATE) AND THE SOLUNAR CODE WAS 1 (WHERE 1=MAJOR,
     2=MINOR, AND 3=TRANSITION). * * *
 140 REM * * * NOTE:  TIME UNITS ARE MEASURED IN MINUTES FROM
     SUBTRACTING THE STARTING TIME FROM THE ENDING TIME; WHEN
     STARTING TIME IS 659 AND ENDING TIME IS 701, THE COMPUTER
     WILL COUNT FISHING TIME AS 42 MINUTES WHEN IT IS REALLY 2
     MINUTES.  THEREFORE, A SEPERATE DATA LINE MUST BE WRITTEN
     FOR EACH EVENT THAT PASSES FROM ONE HOUR TO THE NEXT . . .
     THIS EXAMPLE MUST BE WRITTEN IN 2 LINES:  THE FIRST WITH A
     STARTING TIME OF 659 AND AN ENDING TIME OF 660 AND THE
     SECOND WITH A STARTING TIME OF 700 AND AN ENDING TIME OF
     701. * * *
1000 DATA 0
1010 READ D
1020 IF D=0 THEN GOTO 1060
1030 READ T1,T2,P,S,C,W$,M$,L
1040 T0=T2-T1
1050 TT=TT+T0
1060 IF D=0 THEN PRINT "TOTAL TIME = "TT
1070 FOR X=1TO8
1080 FOR Y=1TO3
1090 Z=100*(8*(Y-1)+(X-1))
1100 W=Z+100
1110 IF D>0 THEN GOTO 1170
1120 PRINT "TIME OF DAY "Z" MINUTES:  "T(X,Y)" PERCENT:  "
     T(X,Y)/TT
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1130 IF X=3 THEN IF Y=3 THEN INPUT SPACER
1140 IF X=6 THEN IF Y=3 THEN INPUT SPACER
1150 ET(X,Y)=T(X,Y)*F/TT
1160 GOTO 1180
1170 IF Z<=T2 THEN IF W>=T2 THEN GOTO 1200
1180 NEXT Y
1190 NEXT X
1200 IF D>0 THEN T(X,Y)=T(X,Y)+TO
1210 FOR T=1TO3
1220 IF D>0 THEN GOTO 1270
1230 PRINT "PRESSURE "T" MINUTES:  "P(T)" PERCENT:  "P(T)/TT
1240 EP(T)=P(T)*F/TT
1250 IF T= 3 THEN INPUT SPACER
1260 GOTO 1280
1270 IF P=T THEN P(T)=P(T)+TO
1280 NEXT T
1290 FOR U=1TO4
1300 IF D>0 THEN GOTO 1350
1310 PRINT"SKY CONDITION "U" MINUTES:  "S(U)" PERCENT:  "S(U)/TT
1320 ES(U)=S(U)*F/TT
1330 IF U=4 THEN INPUT SPACER
1340 GOTO 1360
1350 IF S=U THEN S(U)=S(U)+TO
1360 NEXT U
1370 FOR V=1TO3
1380 IF D>0 THEN GOTO 1420
1390 PRINT"WATER TEMP "V" MINUTES:  "Q(V)" PERCENT:  "Q(V)/TT
1400 EQ(V)=Q(V)*F/TT
1410 GOTO 1430
1420 IF C=V THEN Q(V)=Q(V)+TO
1430 NEXT V
1440 IF W$="O" THEN WD=1 ELSE IF W$="N" THEN WD=2 ELSE IF W$="S"
     THEN WD=3 ELSE IF W$="E" THEN WD=4 ELSE IF W$="W" THEN WD=5
1450 IF D=0 THEN GOTO 1480
1460 DW(WD)=DW(WD)+TO
1470 GOTO 1520
1480 FOR WD=1TO5
1490 PRINT"WIND DIRECTION "WD" MINUTES:  "DW(WD)" PERCENT:  "
     DW(WD)/TT
1500 ED(WD)=DW(WD)*F/TT
1510 NEXT WD
1520 IF M$="O" THEN WM=1 ELSE IF M$="L" THEN WM=2 ELSE IF M$="M"
     THEN WM=3 ELSE IF M$="S" THEN WM=4
1530 IF D=0 THEN GOTO 1560
1540 MW(WM)=MW(WM)+TO
1550 GOTO 1610
1560 FOR WM=1TO4
1570 PRINT"WIND MAGNITUDE "WM" MINUTES:  "MW(WM)" PERCENT:  "
     MW(WM)/TT
1580 IF WM=4 THEN INPUT SPACER
1590 EM(WM)=MW(WM)*F/TT
1600 NEXT WM
```

```
1610 FOR J=1TO3
1620 IF D>0 THEN GOTO 1660
1630 PRINT"SOLUNAR "J" MINUTES:  "L(J)" PERCENT:  "L(J)/TT
1640 EL(J)=L(J)*F/TT
1650 GOTO 1670
1660 IF L=J THEN L(J)=L(J)+TO
1670 NEXT J
1680 FOR R=1TO6
1690 IF D>0 THEN GOTO 1770
1700 CNT=CNT+OT(R)
1710 IF R=5 THEN OT(6)=TT-CNT
1720 PRINT"LUNAR "R" MINUTES:  "OT(R)" PERCENT:  "OT(R)/TT
1730 EO(R)=OT(R)*F/TT
1740 IF R=5 THEN PRINT"LUNAR 6 MINUTES:  "OT(6)" PERCENT:  "
     OT(6)/TT
1750 IF R=5 THEN INPUT SPACER
1760 GOTO 1800
1770 IF D=LD(R) THEN IF T1>=LT(R) THEN OT(R)=OT(R)+TO ELSE IF
     T2>=LT(R) THEN OT(R)=OT(R)+T2-LT(R)
1780 IF D=HD(R) THEN IF T2<=HT(R) THEN OT(R)=OT(R)+TO ELSE IF
     T1<=HT(R) THEN OT(R)=OT(R)+HT(R)-T1
1790 IF D>LD(R) THEN IF D<HD(R) THEN OT(R)=OT(R)+TO
1800 NEXT R
1810 IF D>0 THEN GOTO 1010
1900 DATA 281, 102, 731, 1115, 1, 1, 2, N, M, 3
1910 REM * * * LINES 1900 TO 2990 RESERVED FOR DATA OF FISH
     CAUGHT * * *
1920 REM * * * DATA MUST BE ENTERED HERE FOR EACH FISH CAUGHT AS
     FOLLOWS:  LENGTH, RELATIVE WEIGHT, DATE, TIME CAUGHT, AND
     CODES FOR PRESSURE, SKY CONDITION, WATER TEMPERATURE, WIND
     DIRECTION, WIND MAGNITUDE, AND SOLUNAR PERIOD. * * *
1930 REM * * * INTERPRETATION OF LINE 1900:  THIS LARGEMOUTH BASS
     WAS 281 mm IN TOTAL LENGTH, HAD A RELATIVE WEIGHT VALUE OF
     102, AND WAS CAUGHT ON JULY 31 AT 11:15 (AM).  AT THE TIME
     THE FISH WAS CAUGHT, PRESSURE WAS 1 (STEADY), SKY CONDITION
     WAS 1 (SUNNY), WATER TEMPERATURE WAS 2 (OVER 21 TO 24 C),
     WIND DIRECTION WAS N (NORTH), WIND MAGNITUDE WAS M
     (MODERATE), AND SOLUNAR PERIOD WAS 3 (TRANSITION).
     {SUGGESTED CODES ARE GIVEN IN LINE 130}. * * *
3000 IF N=F THEN GOTO 3040
3010 READ LN, WR, DY, TD, PR, SC, WT, WD$, WM$, SO
3040 FOR X=1TO8
3050 FOR Y=1TO3
3060 IF N=F THEN GOTO 3070 ELSE GOTO 3130
3070 PRINT"TIME OF DAY "100*(8*(Y-1)+(X-1))" OBSERVED:  "OZ(X,Y)
     " EXPECTED:  "ET(X,Y)
3080 IF X=4 THEN IF Y=3 THEN INPUT SPACER
3090 IF X=8 THEN IF Y=3 THEN INPUT SPACER
3100 XT=XT+(OZ(X,Y)-ET(X,Y))↑2/ET(X,Y)
3110 IF X=8 THEN IF Y=3 THEN PRINT"CHI-SQUARED, TIME OF DAY = "XT
3120 GOTO 3140
```

```
3130 IF TD>=100*(8*(Y-1)+(X-1)) THEN IF TD<+100*(8*(Y-1)+X) THEN
     OZ(X,Y)=OZ(X,Y)+1
3140 NEXT Y
3150 NEXT X
3160 FOR T=1TO3
3170 IF N=F THEN GOTO 3180 ELSE GOTO 3240
3180 IF EP(T)=0 THEN GOTO 3250
3190 XP=XP+OP(T)-EP(T))↑2/EP(T)
3200 PRINT"PRESSURE "T" OBSERVED:  "OP(T)" EXPECTED:  "EP(T)
3210 IF T=3 THEN PRINT "CHI-SQUARED, PRESSURE = "XP
3220 IN T=3 THEN INPUT SPACER
3230 GOTO 3250
3240 IF PR=T THEN OP(T)=OP(T)+1
3250 NEXT T
3260 FOR U=1TO4
3270 IF N=F THEN GOTO 3280 ELSE GOTO 3320
3280 XS=XS+(OS(U)-ES(U))↑2/ES(U)
3290 PRINT"SKY CONDITION "U" OBSERVED:  "OS(U)" EXPECTED:  "ES(U)
3300 IF U=4 THEN PRINT"CHI-SQUARED, SKY CONDITION = "XS
3310 GOTO 3330
3320 IF SC=U THEN OS(U)=OS(U)+1
3330 NEXT U
3340 FOR V=1TO3
3350 IF N=F THEN GOTO 3360 ELSE GOTO 3410
3360 XQ=XQ+(OQ(V)-EQ(V))↑2/EQ(V)
3370 PRINT"WATER TEMPERATURE "V" OBSERVED:  "OQ(V)" EXPECTED:  "
     EQ(V)
3380 IF V=3 THEN PRINT"CHI-SQUARED, WATER TEMPERATURE = "XQ
3390 IF V=3 THEN INPUT SPACER
3400 GOTO 3420
3410 IF WT=V THEN OQ(V)=OQ(V)+1
3420 NEXT V
3430 IF N=F THEN GOTO 3450
3440 IF WD$="O" THEN DD=1 ELSE IF WD$="N" THEN DD=2 ELSE IF WD$=
     "S" THEN DD=3 ELSE IF WD$="E" THEN DD=4 ELSE IF WD$="W" THEN
     DD=5
3450 FOR WD=1TO5
3460 IF N=F THEN GOTO 3470 ELSE GOTO 3520
3470 XD=XD+(OD(WD)-ED(WD))↑2/ED(WD)
3480 PRINT"WIND DIRECTION "WD" OBSERVED:  "OD(WD)" EXPECTED:  "
     ED(WD)
3490 IF WD=5 THEN PRINT"CHI-SQUARED, WIND DIRECTION = "XD
3500 IF WD=5 THEN INPUT SPACER
3510 GOTO 3530
3520 IF DD=WD THEN OF(WD)=OD(WD)+1
3530 NEXT WD
3540 IF N=F THEN GOTO 3560
3550 IF WM$="O" THEN MM=1 ELSE IF WM$="L" THEN MM=2 ELSE IF WM$=
     "M" THEN MM=3 ELSE IF WM$="S" THEN MM=4
3560 FOR WM=1TO4
3570 IF N=F THEN GOTO 3580 ELSE GOTO 3620
3580 XM=XM+(OM(WM)-EM(WM))↑2/EM(WM)
```

```
3590 PRINT"WIND MAGNITUDE "WM" OBSERVED:  "OM(WM)" EXPECTED:  "
     EM(WM)
3600 IF WM=4 THEN PRINT"CHI-SQUARED, WIND MAGNITUDE = "XM
3610 GOTO 3630
3620 IF MM=WM THEN OM(WM)=OM(WM)+1
3630 NEXT WM
3640 FOR J=1TO3
3650 IF N=F THEN GOTO 3660 ELSE GOTO 3710
3660 XL=XL+(OL(J)-EL(J))↑2/EL(J)
3670 PRINT"SOLUNAR "J" OBSERVED:  "OL(J)" EXPECTED:  "EL(J)
3680 IF J=3 THEN PRINT"CHI-SQUARED, SOLUNAR = "XL
3690 IF J=3 THEN INPUT SPACER
3700 GOTO 3720
3710 IF SO=J THEN OL(J)=OL(J)+1
3720 NEXT J
3730 FOR O=1TO6
3740 IF N=F THEN GOTO 3750 ELSE GOTO 3830
3750 IF EO(O)=0 THEN PRINT "LUNAR "O" DROPPED" ELSE GOTO 3770
3760 GOTO 3900
3770 PRINT"LUNAR "O" OBSERVED:  "OO(O)" EXPECTED:  "EO(O)
3780 XO=XO+(OO(O)-EO(O))↑2/EO(O)
3790 IF O=6 THEN PRINT"CHI-SQUARED, LUNAR = "XO
3800 IF O=5 THEN GOTO 3810 ELSE GOTO 3900
3810 OO(6)=F-LL
3820 GOTO 3900
3830 IF DY<HD(O) THEN IF DY>LD(O) THEN GOTO 3880
3840 OF DY=LD(O) THEN GOTO 3850 ELSE IF DY=HD(O) THEN GOTO 3860
     ELSE GOTO 3900
3850 IF TD>LT(O) THEN GOTO 3880 ELSE GOTO 3900
3860 IF TD<HT(O) THEN GOTO 3880 ELSE GOTO 3900
3870 GOTO 3900
3880 OO(O)=OO(O)+1
3890 LL=LL+1
3900 NEXT O
3910 N=N+1
3920 IF N=F+1 THEN END ELSE GOTO 3000
```

APPENDIX B - COMPUTER OUTPUT

Figure 1: Number of largemouth bass caught during each period of day:

time period	time fished (minutes)	percent of time	observed # caught	expected # caught
000 - 259	664	7.0	2	4.2
300 - 559	657	7.0	0	4.1
600 - 859	1231	13.1	10	7.7
900 - 1159	1306	13.8	12	8.2
1200 - 1459	1231	13.1	5	7.7
1500 - 1759	1078	11.4	8	6.7
1800 - 2059	1565	16.6	19	9.8
2100 - 2359	1706	18.1	3	10.7
Total	9438	100.1	59	59.1

Chi-squared value (7 degrees of freedom): 23.1.

Figure 2: Number and percentage (in parentheses) of largemouth bass of each size range caught during low-light levels, high-light levels, and night:

size range(mm)	low light	high light	dark	total
150 - 199	1 (16.7)	4 (66.7)	1 (16.7)	6 (10.2)
200 - 249	3 (33.3)	5 (55.6)	1 (11.1)	9 (15.3)
250 - 299	12 (50.0)	12 (50.0)	0	24 (40.7)
300 - 349	6 (66.7)	3 (33.3)	0	9 (15.3)
350 - 399	3 (50.0)	2 (33.3)	1 (16.7)	6 (10.2)
400 - 470	4 (80.0)	0	1 (20.0)	5 (8.5)
Total	29 (49.2)	26 (44.1)	4 (6.8)	59 (100)

Figure 3: Number of largemouth bass caught in each surface temperature:

temperature range (C)	time fished (minutes)	percent of time	observed # caught	expected # caught
18-21	2231	23.6	26	13.9
over 21-24	1958	20.7	7	12.2
over 24-27	5249	55.6	26	32.8
total	9438	99.9	59	58.9

Chi-squared value (2 degrees of freedom): 14.1.

Figure 4: Number of largemouth bass caught during each sky condition:

sky condition	time fished (minutes)	percent of time	observed # caught	expected # caught
sunny	2886	30.6	29	18.0
partly cloudy	1999	21.2	15	12.5
cloudy	1055	11.2	7	6.6
dark	3498	37.1	8	21.9
total	9438	100.1	59	59.0

Chi-squared value (3 degrees of freedom): 16.0.

Figure 5: Number of largemouth bass caught during each moon phase:

moon phase	time fished (minutes)	percent of time	observed # caught	expected # caught
full	2538	26.9	27	15.8
new	1549	16.4	9	9.7
1st quarter	521	5.5	3	3.3
3rd quarter	316	3.3	0	2.0
transition	4514	47.8	20	28.2
total	9438	99.9	59	59.0

Chi-squared value (4 degrees of freedom): 12.4.

Figure 6: Number of largemouth bass caught during each barometric pressure.

barometric pressure	time fished (minutes)	percent of time	observed # caught	expected # caught
steady	3828	53.9	21	24.3
rising	2672	37.6	22	16.9
falling	600	8.5	2	3.8
total	7100	100.0	45	45.0

Chi-squared value (2 degrees of freedom): 2.8.

Figure 7: Number of largemouth bass caught during each wind direction:

wind direction	time fished (minutes)	percent of time	observed # caught	expected # caught
north	1385	14.7	9	8.7
south	1825	19.3	6	11.4
east	779	8.3	3	4.9
west	4093	43.4	31	25.6
none	1356	14.4	10	8.4
total	9438	100.1	59	59.0

Chi-squared value (4 degrees of freedom): 4.7.

Figure 8: Number of largemouth bass caught during each wind magnitude:

wind magnitude	time fished (minutes)	percent of time	observed # caught	expected # caught
none	1356	14.4	10	8.5
light	3755	39.8	23	23.5
moderate	2142	22.7	19	13.4
strong	2185	23.2	7	13.7
total	9438	100.1	59	59.1

Chi-squared value (3 degrees of freedom): 5.9.

Figure 9: Number of largemouth bass caught during each solunar period:

solunar period	time fished (minutes)	percent of time	observed # caught	expected # caught
major	1483	15.7	7	9.3
minor	1229	13.0	5	7.7
transition	6726	71.3	47	42.0
total	9438	100.0	59	59.0

Chi-squared value (2 degrees of freedom): 2.1.